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ABSTRACT

A study attempted to determine if diurnal (daily cyclical) variations were present during maximal exercise. The subjects' (30 female undergraduate physical education majors) oxygen consumption and heart rates were monitored while they walked on a treadmill on which the grade was raised every minute. Each subject was tested for maximal oxygen consumption on three different occasions. The times of day for testing periods were between 0800-0830, 1200-1230, and 1600-1630 hours. Data related to physical performances as measured by the total number of seconds subjects walked on the treadmill revealed significant differences between 0800 and 1200 and among 0800, 1200, and 1600. Significant increases in maximal oxygen consumption were noted between 0800 and 1200 and 0800 and 1600. The exact nature of this variation is unknown; however, an increased blood flow to the working muscles can be postulated. The results of this study imply the need for researchers to report the time at which tests for maximal performance are administered. Additionally, when maximal performances are being compared, subjects should be tested at the same time of day to reduce the variability due to diurnal variations. (JMK)

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INTRODUCTION

Although human circadian rhythms have been studied in relation to several physiological parameters, little data are available on variations during maximal exercise. This is surprising when one considers the potential importance of rhythmicity when assessing physical fitness.

Resting variations of circulatory and respiratory system functions were studied by Booning, Schweigart, and Kunze (1974), who reported a significant increase in hemoglobin concentration between 7 a.m. and 6 p.m. and a significant decrease in per cent saturation of oxygen in venous blood. Wylicil and Weber (1969), studied airway resistance in normal patients and those who had severe airway obstructions. They concluded that diurnal variations in respiratory functions were factors in deciding when to administer lung function tests. Buskirk, Iampietro, and Welch (1957) found that as the day progressed, resting metabolism gradually elevated, reaching a peak at 8 p.m.

Oxygen consumption was studied by Ribisl (1977) who noted a "slightly but significant" elevation in submaximal oxygen consumption in the late afternoon as compared with early morning. Investigating physical performances, Rodahl (1976) noted significantly better times of competitive olympic swimmers during the evening than in the morning. Conroy and O'brien (1974) observed rowers, swimmers, and track and field athletes and noted a general improvement in performance during the evening.

Whether the diurnal variations noted during performance or submaximal conditions could be extrapolated to maximal exercise was a question which had not been previously investigated. Therefore, the purpose of this study was to determine if diurnal variations were present during maximal exercise.

METHODS

Thirty female undergraduate physical education majors at Middle Tennessee State University volunteered as subjects. During the initial visit to the laboratory, subjects completed an informed consent form and were oriented to treadmill walking and testing protocol. They were instructed to abstain from eating at least three hours prior to each testing session, and to refrain from vigorous physical activity the day prior to testing. Each subject reported to the laboratory in shorts and running shoes approximately thirty minutes prior to each testing session. Upon entering the laboratory, they were weighed and instructed to recline on a bed for at least twenty minutes. Approximately two minutes prior to the beginning of the exercise test, a pre-exercise heart rate was recorded as the subject stood on the treadmill. Treadmill protocol was similar to the continuous test developed by Balke and Ware (1959). Speed of the treadmill (Quniton 24-72) was 3.4 m.p.h., and the subject walked at zero per cent grade for the first two minutes. The grade was then raised to 2% and increased 1% each minute until exhaustion.

Leveling off of oxygen consumption with increased workload was used when possible to indicate that maximal performance had been reached. In those subjects who did not have a plateau in oxygen consumption, the peak oxygen consumption value measured was considered to be maximal.

Heart rate was continuously recorded by means of a Hewlett Packard 100B single channel recorder. Maximal heart rate was considered to be the highest recorded during the treadmill test. Subjects breathed through a modified Ottis McKerrow valve and expired air was collected in meteorological balloons each minute of exercise.

The balloon was evacuated into a 350 liter wet gasometer (Collins Instruments, Braintree, Mass.). A Beckman E-2 and LB2 oxygen and carbon dioxide analyzers, respectively were used to analyze aliquots of expired air. Reference gases for calibration of the analyzers were verified with microscholander techniques, and all metabolic measures were determined by standard techniques of spiromtry.

Each subject was tested for maximal oxygen consumption on three different occasions. The times of day for testing periods were between 0800-0830, 1200-1230, and 1600-1630 hours. Only one test was administered each day and the sequence of administration was according to a Latin square as an effort to eliminate the training effect of testing procedures. One-way analysis of variance with repeated measures upon one variable was used to compare the results. When the .05 level of significance was obtained, Newman Kuels' technique was used to locate where differences were located.

RESULTS AND DISCUSSION

Descriptive data for the subjects and laboratory conditions are presented in Table 1. The subjects were fairly homogenous with respect to age, height, and weight. Experimentation of this nature requires that the climatic conditions surrounding the exercise remain relatively constant. Any increase in temperature or humidity will effect the ability of subjects to perform maximal work. Analysis of laboratory conditions during the three testing sessions revealed differences which were neither clinically nor statistically significant.

In order to assess the reproductibility of the data, fifteen subjects were retested during the three testing periods. These data are presented in Table 2. All intraclass correlation coefficients were significant at the .05 level. These coefficients and the standard deviations noted in Table 3 indicate that these data are more easily reproduced early in the morning than in the afternoon. Buskirk et al. (1957) noted similar trends in data related to resting metabolic measures.

Analysis of heart rates indicated no significant differences in pre-exercise rates between 0800 and 1200 or between 1200 and 1600. The increase of 5.7 beats per minute between 0800 and 1600 was significant at the .05 level. This diurnal increase in heart rate has long been known to exist and documented by Aschoff (1966), Halberg (1960), Kaneko, Zechman and Smith (1968), Kleitman and Ramsaroop (1948), and Mills (1960). Kleitman and Ramsaroop (1948) attributed this increase in heart rate to an accompanying increase in body temperature.

The values obtained for maximal heart rate were within the range of data reported by Humphrey and Falls (1971) and McArdle et al. (1969). No significant differences were noted among the maximal heart rates recorded. If maximal heart rate is predicted by considering 220 subject's age, then the average values reported are slightly less, but not significantly different from the predicted values. Additionally, the plateau of oxygen consumption was the criteria for terminating 82.2 per cent of the tests administered.

The data related to physical performances as measured by the total number of seconds subjects walked on the treadmill revealed significant differences between 0800 and 1200 and between 0800 and 1600. These data are similar to that reported by Rodahl (1976) and Conroy and O'brien, who reported improvement in performance in the afternoon as compared to morning.

The values obtained for maximal oxygen consumption were within the range of data reported by Astrand (1952), Drinkwater (1973), Howley (1977), Humphrey and Falls (1971), Katch et al. (1969), McArdle et al. (1972), and Metheny et al. (1942). Significant increases in maximal oxygen consumption were noted between 0800 and 1200 and between 0800 and 1600. The exact nature of this variation is unknown; however, an increased blood flow to the working muscles could be postulated. According to Reeves (1961), one of the possible factors limiting maximal work is the lack of adequate blood flow to the muscle. Kaneko et al. (1968) noted a diurnal variation, generally peaking in the late afternoon of blood flow to forearm muscles prior to and after exercise. If this diurnal increase in blood flow exists in the muscles involved in treadmill walking, then an increase in maximal oxygen consumption would result from more oxygen being available to the working muscles.

The results of this study imply the need for researchers to report the time tests for maximal performance are administered. Additionally, when maximal performances are being compared, subjects should be tested at the same time of day in order to reduce the variability due to the diurnal variations noted in this study.

TABLE 2

INTRACLASS CORRELATION COEFFICIENTS (N=15)

VARIABLE	TIME		
	0800	1200	1600
Pre-exercise heart rate	.90	.93	.90
Maximal heart rate	.90	.91	.89
Maximal oxygen consumption	.90	.88	.85
Treadmill Time	.91	.89	.86

TABLE 1

PHYSICAL CHARACTERISTICS OF SUBJECTS

AND LABORATORY CONDITIONS

Variable	Mean ± SD	Range
Subjects (N=30)		
Age (yrs.)	21.10 ± 1.2	19.5 - 23.3
Height (cm)	166.4 ± 1.3	62.0 - 67.0
Weight (kg)	57.3 ± 5.3	118.0 - 135.0
Laboratory Conditions	(Degrees Celcius)	
Dry Bulb	20.80 ± 1.20	18.5 - 22.5
Wet Bulb	14.04 ± 2.25	11.11 - 16.88

TABLE 2

DIURNAL VARIATIONS IN HEART RATE AND OXYGEN CONSUMPTION

Variable	TIME 0800	1200	1600	F
Pre-exercise HR				
Mean_+SD	84.9 ± 4.3	88.24 ± 5.2	90.6 ± 5.3	3.60*
Maximal HR				
Mean ± SD	196.0 ± 9.8	198.1 ± 9.8	198.4 ±10.0	.22
Oxygen consumption (ml/kg)				
Mean ± SD	35.4 ± 2.9	40.0 ± 3.1	40.3 ± 3.3	8.00*
Treadmill times				
Mean ± SD	14.5 ± 1.7	16.03 ± 1.8	17.01± 1.8	5.56*

* Significant at .05 level.

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